

# Preliminary Results for PFAS-AWARE: Health Effects Study on Poly- and Perfluoroalkyl Substances

PFAS AWARE Study Team: Adgate, Barton, Higgins, Mass, McDonough, Starling

[www.PFAS-AWARE.org](http://www.PFAS-AWARE.org)

April 25<sup>th</sup> 2019

Funded by NIEHS Grant R21ES029394



**John Adgate,**  
Colorado School of  
Public Health



**Carrie McDonough,**  
Colorado School of  
Mines



**Chris Higgins,**  
Colorado School of  
Mines



**Kelsey Barton,**  
Colorado School of  
Public Health



**Anne Starling,**  
Colorado School of  
Public Health



**Sarah Mass,**  
Colorado School of  
Mines

# Funders: National Institute of Environmental Health Sciences (NIH)

## Objectives:

1. Understand the relationship between exposure to PFASs in drinking water and how quickly the body accumulates and/or eliminates various PFASs
2. Evaluate how exposure to PFASs affects health

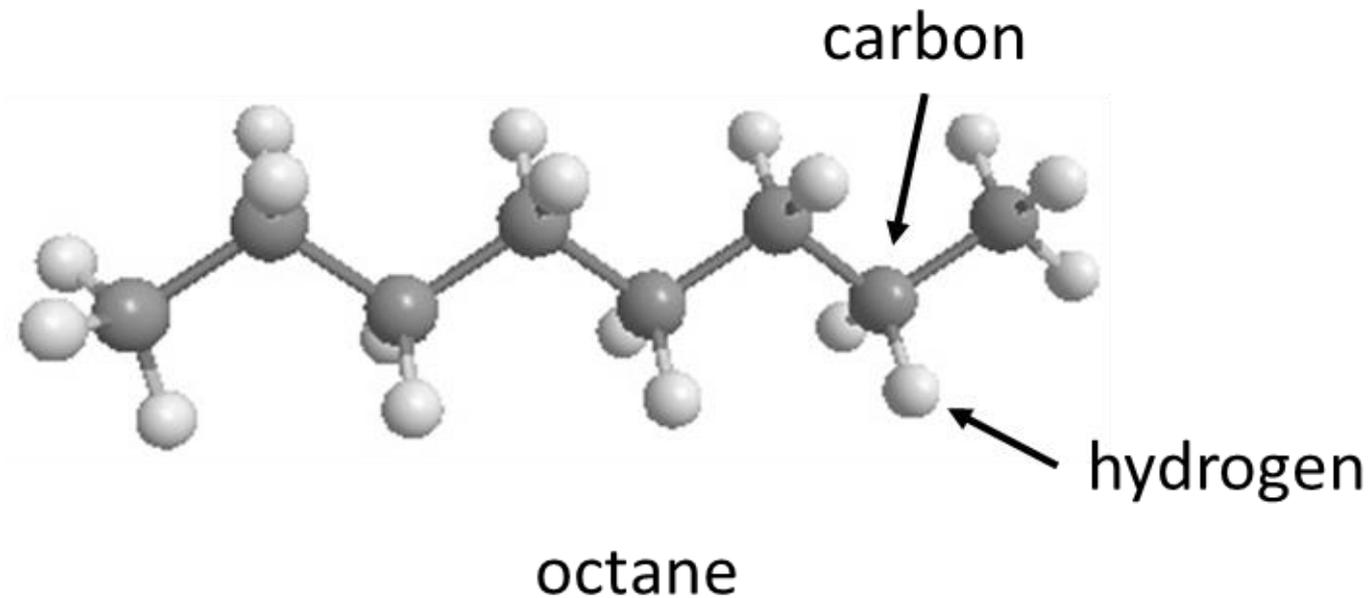
# Talk Roadmap

- PFAS-AWARE Study
  - Background on PFASs
  - Timeline & study progress
- Presentation of April 2019 blood test results
- Review of water results from December 2018 presentation
- Presentation of April 2019 water test results
- Future directions
- Questions

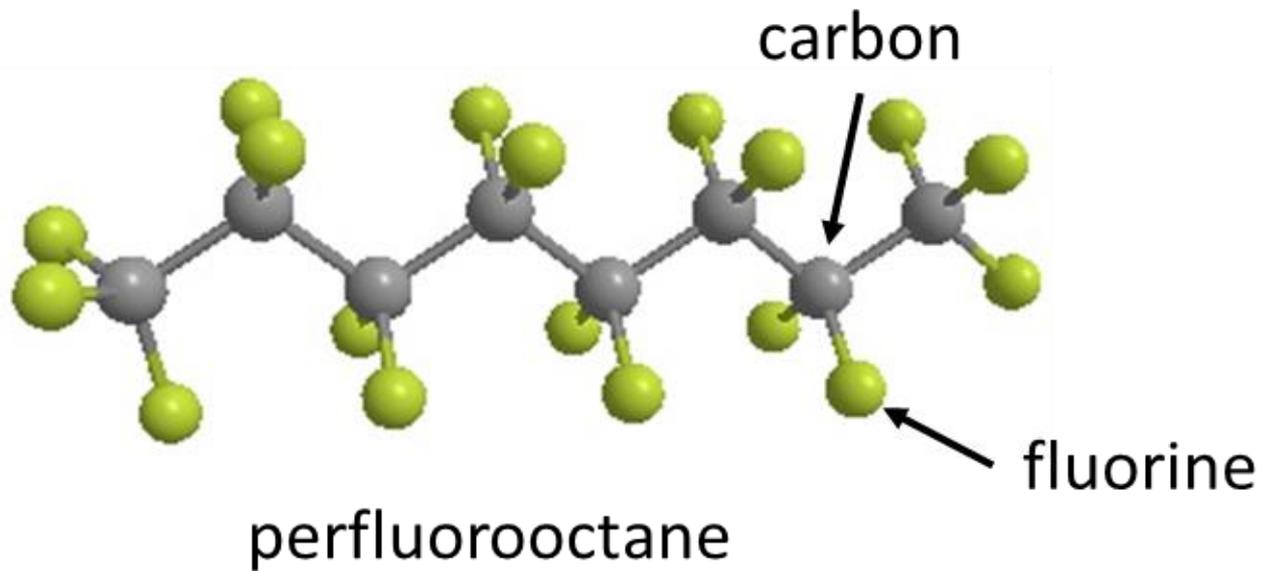
# PFAS Exposure in Fountain, Security and Widefield Wells

- AFFF (Aqueous Film Forming Foam) was used at airports, military installations, fire-fighting training sites, manufacturing sites, and other places.
  - PFASs from AFFF are a different mixture from the one in consumer products. This includes PFHxS (perfluorohexane sulfonate) and related substances
  - Less is known about exposure and health effects of PFHxS than PFOA/PFOS
- **If you are on one of the public water systems (Fountain, Security, and Widefield) your exposure ended around August 2015 because of changes in water sources or addition of treatment systems**

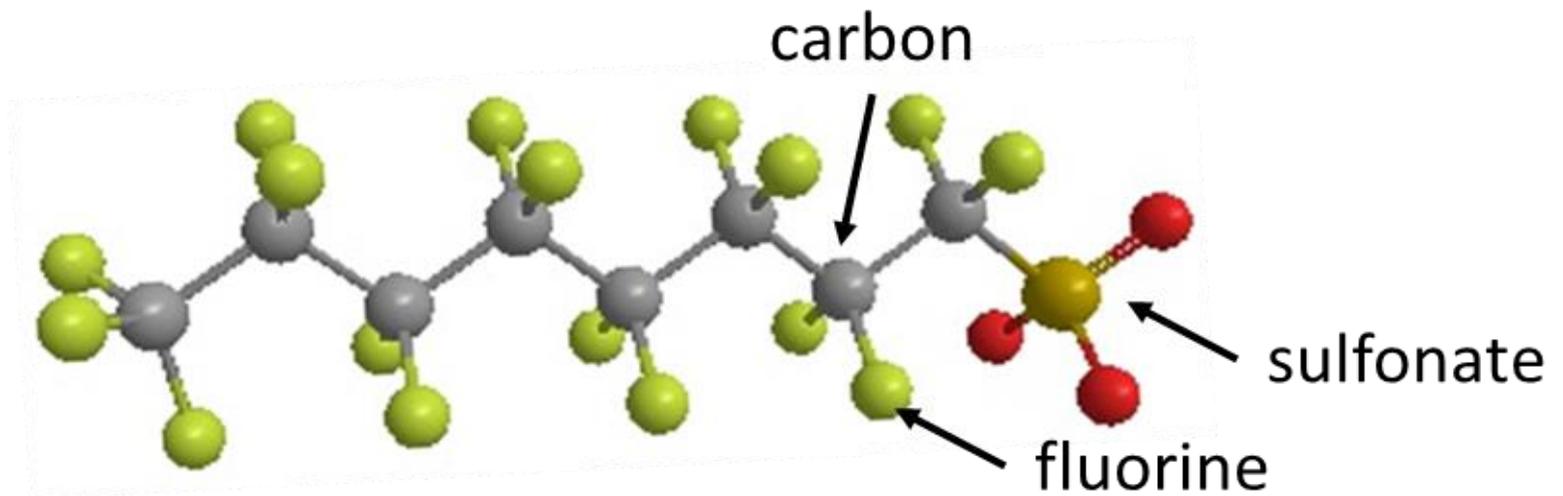
# PFAS Background



# PFAS Background



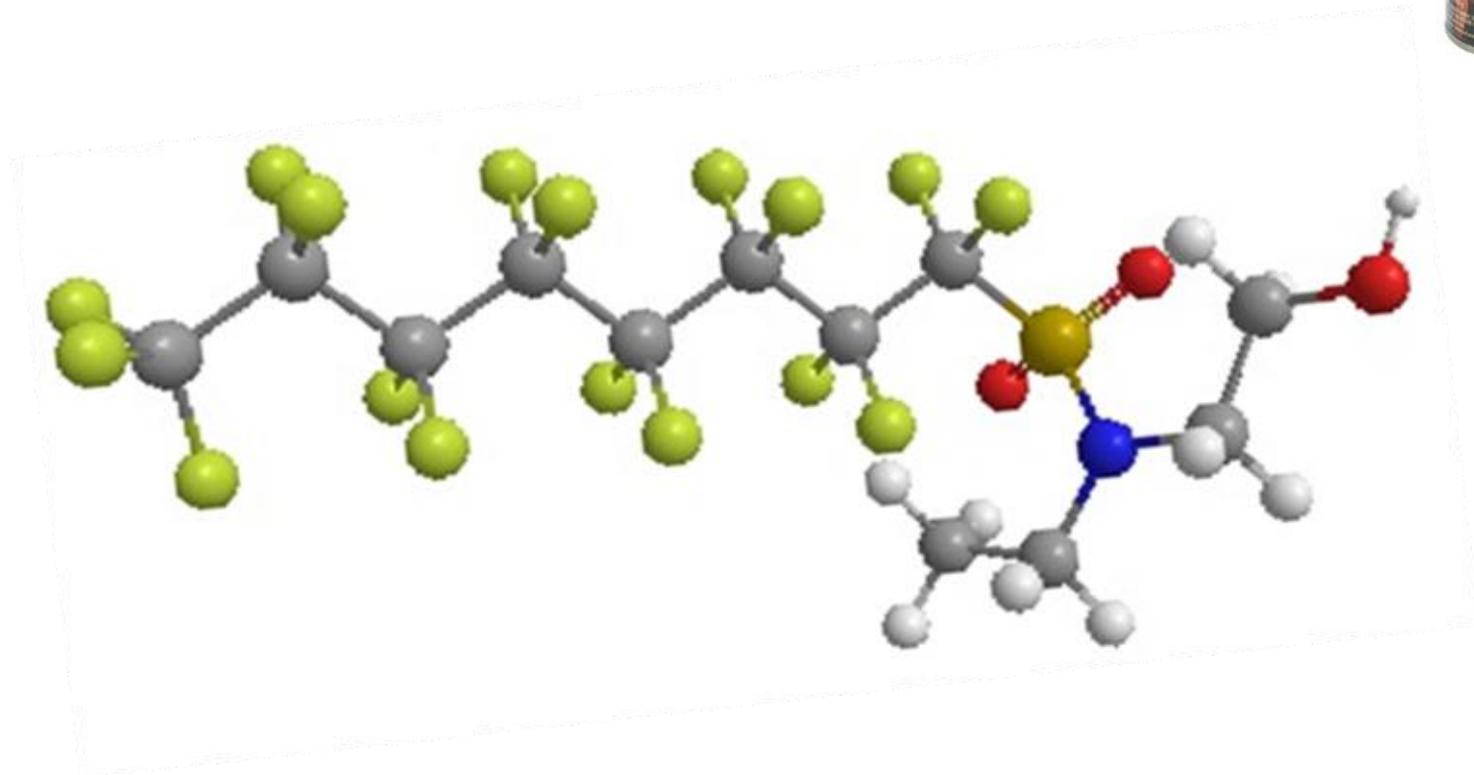
# PFAS Background



perfluorooctane sulfonate

PFOS

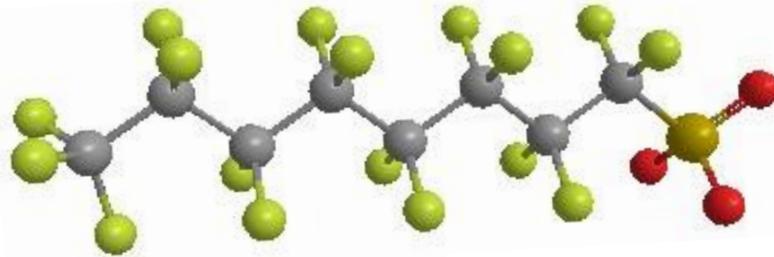
# PFAS Background



N-ethyl perfluorooctane sulfonamidoethanol

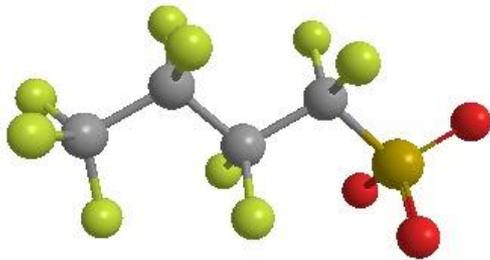
N-Et-FOSE

# PFAS Background

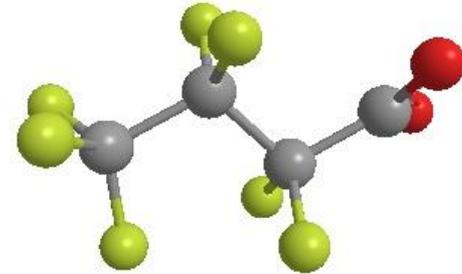


N-ethylperfluorooctane  
sulfonamide N-EOSE

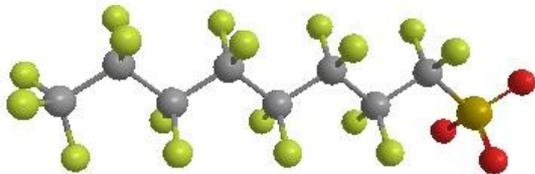
# PFAS Background



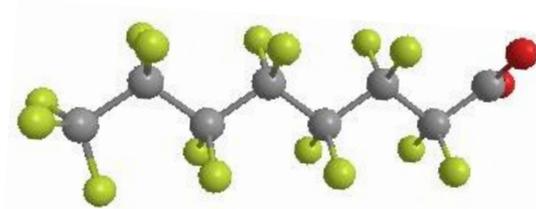
perfluorobutane sulfonate (PFBS)



perfluorobutane carboxylate (PFBA)

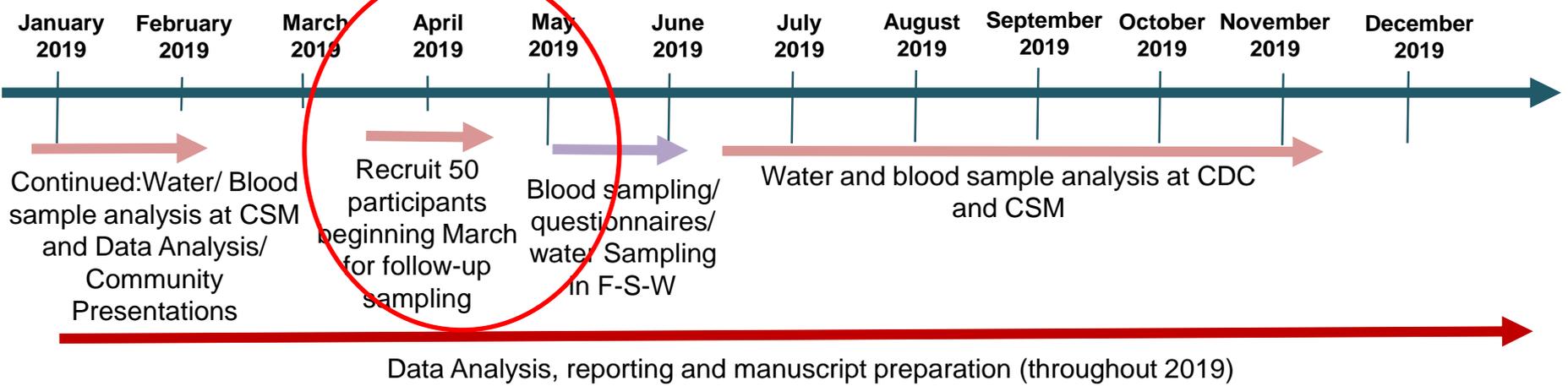
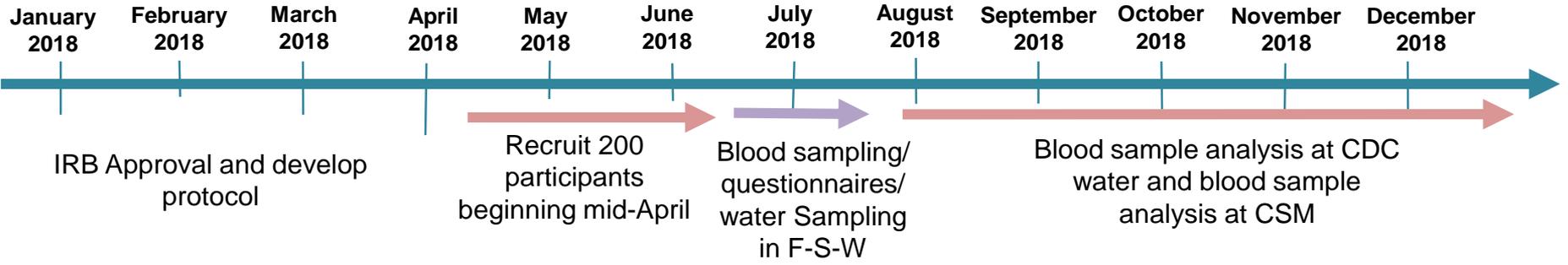


perfluorooctane sulfonate (PFOS)



perfluorooctane carboxylate (PFOA)

# PFAS-AWARE Study Timeline



# Study Progress

- **Year 1: 2018**

- Water Sampling
- Blood Sampling
- Participant Questionnaires



- **Year 2: 2019**

- Blood Sampling
- Questionnaires

# Study Progress

- **Year 2 blood draw:** We have selected a random sample of 50 people to participate in the May, 2019 blood draw. If you have not been contacted as of now, that means you were likely not selected.
- **Residential Histories:** We are going to be asking all participants who were not selected to be in the second blood draw if they'd be willing to complete an additional questionnaire. You will be given \$20 for your time. This information should help us determine when the water first became contaminated.

# Preliminary Blood Sampling Results

- **In December, 2018 we presented about:**
  - 18 PFAS Compounds
  - Total Cholesterol, Triglycerides, HDL Cholesterol and LDL Cholesterol
  - Liver Enzymes: AST, ALT, GGT
- **Results we are sharing today:**
  - Interleukins and Other Cytokines: IL-1 $\beta$ , IL-2, IL-6, IL-10, IFN- $\gamma$  and TNF- $\alpha$
  - Additional 29 PFASs in serum

# Your Letter

The full name of the compound.

Shortened name of the compound.

The point at which half the values are above and half are below.

The number and percent of people in this study who had greater than 0.1 ng/mL of PFAS detected in blood.

The point at which 95% of the values are below.

Chemical Name	Abbreviation	Your Result	Lowest Result found in this Study	50 <sup>th</sup> percentile* for this Study	Highest Result found in this study	Number (%) of participants with detectable levels in this study	50 <sup>th</sup> Percentile* for general U.S. Population	95 <sup>th</sup> Percentile** for general U.S. Population
<b>Perfluoroalkanoic acids</b>								
Perfluoro-n-butanoic acid	PFBA		Below Limit of Detection <sup>^</sup>	Below Limit of Detection <sup>^</sup>	Below Limit of Detection <sup>^</sup>	0 (0%)	--	--
Perfluoro-n-pentanoic acid	PFPeA		Below Limit of Detection <sup>^</sup>	Below Limit of Detection <sup>^</sup>	Below Limit of Detection <sup>^</sup>	0 (0%)	--	--
Perfluoro-n-hexanoic acid	PFHxA		Below Limit of Detection <sup>^</sup>	Below Limit of Detection <sup>^</sup>	0.5	55 (25%)	--	--
Perfluoro-n-heptanoic acid	PFHpA		Below Limit of Detection <sup>^</sup>	Below Limit of Detection <sup>^</sup>	0.5	20 (9%)	Below Limit of Detection <sup>^</sup>	0.200
Perfluoro-n-octanoic acid	PFOA		Below Limit of Detection <sup>^</sup>	2.9	13.8	219 (99.5%)	2.07	5.57
Perfluoro-n-nonanoic acid	PFNA		Below Limit of Detection <sup>^</sup>	0.4	4.2	219 (99.5%)	0.700	2.00

# What Are CDC & NHANES Reference Ranges?

- CDC is the “Centers for Disease Control”
- NHANES is the “National Health and Nutrition Examination Survey”
  - Designed to assess the health and nutrition status of adults and children in the U.S. using interviews, examinations and laboratory testing
  - A nationally representative selection of people participate every other year
  - **Helps to determine U.S. population averages for both diseases, PFAS exposure and other exposures.**

Preliminary Blood Sampling Results  
from 220 Blood Samples:  
April 2019 Results

# Blood Sampling-New PFAS Results:

- Results of serum concentrations for 29 additional PFASs
  - 12 of these 29 compounds were detected in **at least one** study participant.
  - 17 of these 29 compounds were **not** detected in any study participant.
- With the exception of FOSA, none of these compounds have been measured at a national level
  - Can't compare the levels found in this study population to levels found in other areas of the U.S.

## PFAS Results (in ng/ml):

12 compounds were detected in **at least one** study participant

Current Acronym	This Study 50 <sup>th</sup> Percentile	Highest in this Study	Percent Measurable
PFEtCHxS	0.24	1.93	89%
PFPeS	0.22	18.73	81%
PFPrS	<LOD	0.39	25%
8:2 FTS	<LOD	0.10	12%
FOSA	<LOD	0.04	9%
FOSAA	<LOD	0.42	8%
6:2 FTS	<LOD	3.34	4%
CI-PFOS	<LOD	0.04	4%
4:2 FTS	<LOD	0.16	2%
PFDS	<LOD	0.17	1%
PFNS	<LOD	0.02	1%
PFTTrDA	<LOD	0.11	0.5%

**<LOD stands for below the limit of detection.** This means that there was not enough of the compound in the blood sample for the instrument to provide a confident answer.

## PFAS Results (in ng/ml):

17 compounds were **not** detected in any study participant.

Current Acronym	Percent Measurable
PFTeDA	0%
PFHxDA	0%
PFODA	0%
PFDoS	0%
Cl-O-PFUdS	0%
MeFOSA	0%
EtFOSA	0%
10:2 FTS	0%
3:3 FTA	0%
5:3 FTA	0%
7:3 FTA	0%
6:2 FTA	0%
8:2 FTA	0%
10:2 FTA	0%
6:2 FTUA	0%
8:2 FTUA	0%
10:2 FTUA	0%

# What does this mean?

- Again, with the exception of FOSA, none of these compounds have been measured at a national level, so no reference ranges exist
- Most of these substances have not been studied in humans, so health effects are not known
- Now that we know that some of these are present in people exposed to AFFF, we can prioritize them for future studies of persistence and health effects

# Blood Sampling-PFAS Results:

- **How can I avoid additional exposure to PFAS?**
  - If you are on a private well have it checked for PFAS contamination.
  - Limit eating at fast food restaurants or eating microwave meals that use packaging that may be grease repellent.
  - Avoid buying stain- and water-resistant products where possible.
  - Wash hands before eating and keep floors and surfaces clean to reduce possible exposure from PFASs in dust.

# Cytokines: Interleukins

- Produced in the bloodstream, belong to a molecular group called cytokines
- Play an important role in the immune system: **Inflammation**
- There are both pro-inflammatory and anti-inflammatory agents, balance is key
- **IL-1 $\beta$ , IL-6 and IL-8** are all pro-inflammatory cytokines
- **IL-10** is an anti-inflammatory cytokine

**Remember, there is no recommended or established “normal” range for cytokine levels.**

If your cytokine levels are higher or lower compared to the rest of the study population that does not necessarily indicate a health problem. Cytokine levels are affected by many things including diet, exercise and stress. If you are concerned about your results you should consult with your doctor.

# Blood Sampling-Interleukin Results:

	IL-1 $\beta$ (pg/ml):	IL-2 (pg/ml):	IL-6 (pg/ml):	IL-10 (pg/ml):
Study 50 <sup>th</sup> Percentile	< LOD	< LOD	< LOD	< LOD
Study Range	Min: < LOD Max: 0.77	Min: < LOD Max: 0.75	Min:< LOD Max: 32.24	Min:< LOD Max: 1.61
Detected in what Percent of Study participants?	32%	7%	39%	35%
Expected Range	<b>Not Established</b>			

**< LOD:** The interleukin was below the limit of detection, meaning the value was too low to be accurately determined.

**Remember, there is no recommended or established “normal” range for cytokine levels.** If your cytokine levels are higher or lower compared to the rest of the study population that does not necessarily indicate a health problem. Cytokine levels are affected by many things including diet, exercise and stress. If you are concerned about your results you should consult with your doctor.

**We are still working on the analysis of any potential relationships between PFAS exposure and Cytokines**

# Other Cytokines

## Tumor Necrosis Factor:

- Tumor necrosis factors are family of proteins within the cytokine group
- Part of the body's immune response system and can cause cell death
- **TNF- $\alpha$**  is a pro-inflammatory cytokine

## Interferon Gamma (IFN- $\gamma$ ):

- Interferon gamma is a signaling protein.
- Plays an important role in the body's adaptive immune response
- Relates to the fighting off of allergic diseases (like asthma)
- **IFN- $\gamma$** : This cytokine has both pro- and anti-inflammatory properties.

**Remember, there is no recommended or established “normal” range for cytokine levels.**

If your cytokine levels are higher or lower compared to the rest of the study population that does not necessarily indicate a health problem. Cytokine levels are affected by many things including diet, exercise and stress. If you are concerned about your results you should consult with your doctor.

# Blood Sampling-Other Cytokine Results:

	IFN- $\gamma$ (pg/ml):	TNF- $\alpha$ (pg/ml):
Study 50 <sup>th</sup> Percentile	3.11	7.87
Study Range	Min: <LOD Max: 5.27	Min: 1.98 Max: 23.4
Detected in what Percent of Study participants?	72.3%	100%
Expected Range	<b>Not Established</b>	

< **LOD**: The interleukin was below the limit of detection, meaning the value was too low to be accurately determined.

**Remember, there is no recommended or established “normal” range for cytokine levels.**

If your cytokine levels are higher or lower compared to the rest of the study population that does not necessarily indicate a health problem. Cytokine levels are affected by many things including diet, exercise and stress. If you are concerned about your results you should consult with your doctor.

**We are still working on the analysis of any potential relationships between PFAS exposure and Cytokines**

# Preliminary Water Sampling Results: December 2018

- We measured PFASs in the untreated wells that were used by Security, Widefield, and Fountain before the PFAS issue was known
- Since PFASs were discovered in these systems, each water supplier either changed water sources or added treatment systems specifically to remove PFASs
- We also measured PFASs in private well water samples

**Objective:** to understand what residents might have been exposed to in the past, before EPA health advisories were in effect and additional steps were taken to remove PFASs

# Preliminary Water Sampling Results: December 2018

- Measured PFASs in **untreated** water from **private wells** and **public wells** in April-June, 2018
  - 3 in Fountain
  - 3 in Widefield
  - 22 in Security
  - 10 private wells



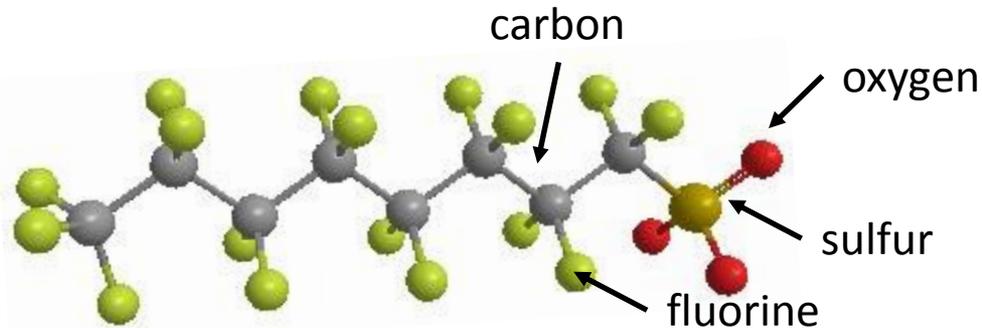
- **Why untreated water?**

While PFASs are now being removed from drinking water, concentrations in blood likely reflect *past exposure*

# Water Conclusions from December 2018 Presentation

- We found 10 different PFASs in more than 80% these samples
- The range of concentrations is large
- The compounds measured are consistent with PFASs derived from fire fighting foam use

# Preliminary Water Sampling Results: April 2019 Results



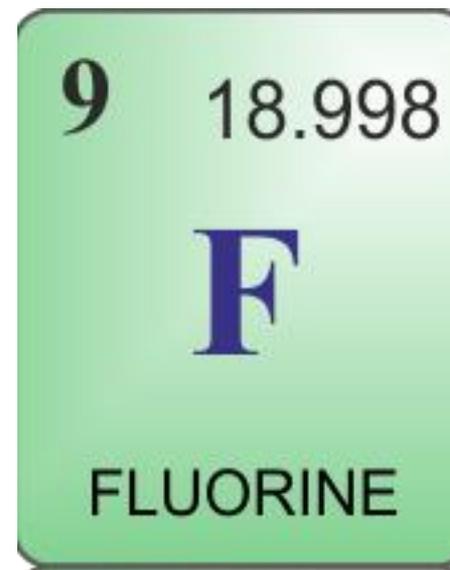
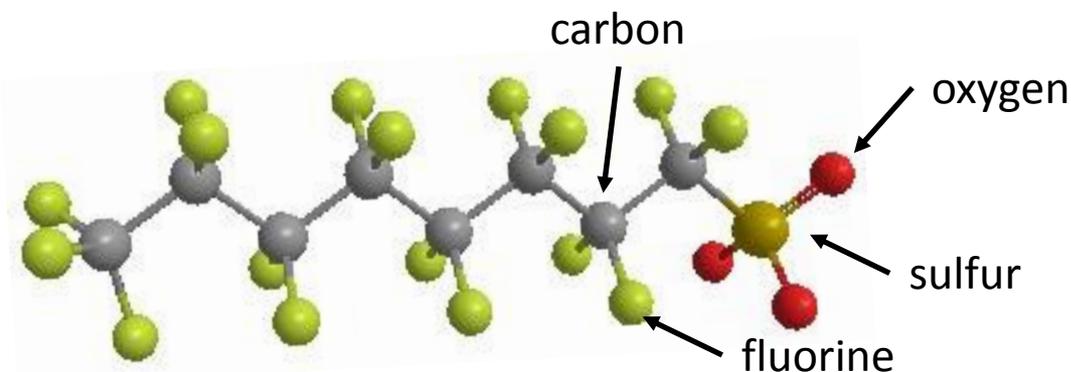
## PERIODIC TABLE OF THE ELEMENTS

PERIOD	GROUP																						
	1 IA	2 IIA											13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA					
1	1 1.008 <b>H</b> HYDROGEN																	2 4.0026 <b>He</b> HELIUM					
2	3 6.94 <b>Li</b> LITHIUM	4 9.0122 <b>Be</b> BERYLLIUM			5 10.81 <b>B</b> BORON													6 12.011 <b>C</b> CARBON	7 14.007 <b>N</b> NITROGEN	8 15.999 <b>O</b> OXYGEN	9 18.998 <b>F</b> FLUORINE	10 20.180 <b>Ne</b> NEON	
3	11 22.990 <b>Na</b> SODIUM	12 24.305 <b>Mg</b> MAGNESIUM																13 26.982 <b>Al</b> ALUMINIUM	14 28.085 <b>Si</b> SILICON	15 30.974 <b>P</b> PHOSPHORUS	16 32.06 <b>S</b> SULPHUR	17 35.45 <b>Cl</b> CHLORINE	18 39.948 <b>Ar</b> ARGON
4	19 39.098 <b>K</b> POTASSIUM	20 40.078 <b>Ca</b> CALCIUM	21 44.956 <b>Sc</b> SCANDIUM	22 47.867 <b>Ti</b> TITANIUM	23 50.942 <b>V</b> VANADIUM	24 51.996 <b>Cr</b> CHROMIUM	25 54.938 <b>Mn</b> MANGANESE	26 55.845 <b>Fe</b> IRON	27 58.933 <b>Co</b> COBALT	28 58.693 <b>Ni</b> NICKEL	29 63.546 <b>Cu</b> COPPER	30 65.38 <b>Zn</b> ZINC	31 69.723 <b>Ga</b> GALLIUM	32 72.64 <b>Ge</b> GERMANIUM	33 74.922 <b>As</b> ARSENIC	34 78.971 <b>Se</b> SELENIUM	35 79.904 <b>Br</b> BROMINE	36 83.798 <b>Kr</b> KRYPTON					
5	37 85.468 <b>Rb</b> RUBIDIUM	38 87.62 <b>Sr</b> STRONTIUM	39 88.906 <b>Y</b> YTRITIUM	40 91.224 <b>Zr</b> ZIRCONIUM	41 92.906 <b>Nb</b> NIOBIUM	42 95.95 <b>Mo</b> MOLYBDENUM	43 (98) <b>Tc</b> TECHNETIUM	44 101.07 <b>Ru</b> RUTHENIUM	45 102.91 <b>Rh</b> RHODIUM	46 106.42 <b>Pd</b> PALLADIUM	47 107.87 <b>Ag</b> SILVER	48 112.41 <b>Cd</b> CADMIUM	49 114.82 <b>In</b> INDIUM	50 118.71 <b>Sn</b> TIN	51 121.76 <b>Sb</b> ANTIMONY	52 127.60 <b>Te</b> TELLURIUM	53 126.90 <b>I</b> IODINE	54 131.29 <b>Xe</b> XENON					
6	55 132.91 <b>Cs</b> CAESIUM	56 137.33 <b>Ba</b> BARIUM	57-71 <b>La-Lu</b> Lanthanide	72 178.49 <b>Hf</b> HAFNIUM	73 180.95 <b>Ta</b> TANTALUM	74 183.84 <b>W</b> TUNGSTEN	75 186.21 <b>Re</b> RHENIUM	76 190.23 <b>Os</b> OSMIUM	77 192.22 <b>Ir</b> IRIDIUM	78 195.08 <b>Pt</b> PLATINUM	79 196.97 <b>Au</b> GOLD	80 200.59 <b>Hg</b> MERCURY	81 204.38 <b>Tl</b> THALLIUM	82 207.2 <b>Pb</b> LEAD	83 208.98 <b>Bi</b> BISMUTH	84 (209) <b>Po</b> POLONIUM	85 (210) <b>At</b> ASTATINE	86 (222) <b>Rn</b> RADON					
7	87 (223) <b>Fr</b> FRANCIUM	88 (226) <b>Ra</b> RADIUM	89-103 <b>Ac-Lr</b> Actinide	104 (267) <b>Rf</b> RUTHERFORDIUM	105 (268) <b>Db</b> DUBNIUM	106 (271) <b>Sg</b> SEABORGIUM	107 (272) <b>Bh</b> BOHRIUM	108 (277) <b>Hs</b> HASSIUM	109 (276) <b>Mt</b> MEITNERIUM	110 (281) <b>Ds</b> DARISTADIUM	111 (280) <b>Rg</b> ROENTGENIUM	112 (285) <b>Cn</b> COPERNICIUM	113 (285) <b>Nh</b> NIHONIUM	114 (287) <b>Fl</b> FLEROVIUM	115 (289) <b>Mc</b> MOSCOVIUM	116 (291) <b>Lv</b> LIVERMORIUM	117 (294) <b>Ts</b> TENNESSE	118 (294) <b>Og</b> OGANESSON					

Legend:

- Metal (Blue)
- Semimetal (Orange)
- Nonmetal (Green)
- Alkali metal (Light Blue)
- Alkaline earth metal (Light Blue)
- Transition metals (Light Blue)
- Lanthanide (Purple)
- Actinide (Purple)
- Chalcogens element (Light Green)
- Halogens element (Light Green)
- Noble gas (Light Green)

STANDARD STATE (25 °C; 101 kPa):  
**Ne** - gas    **Fe** - solid  
**Hg** - liquid    **Tc** - synthetic



Nominal Mass: 499

Exact Mass: 498.9297

We can detect and identify many compounds through high resolution mass spectrometry, even if we don't have an analytical standard for comparison.

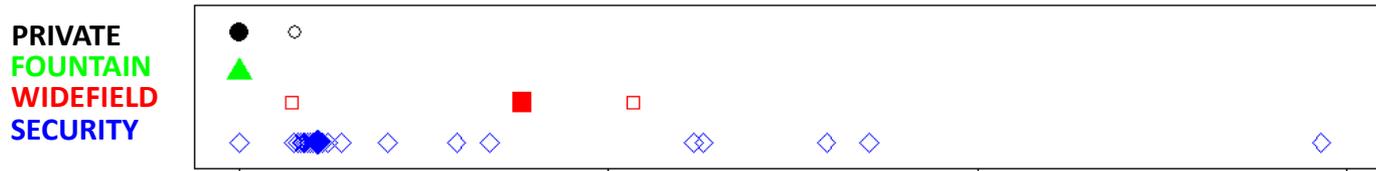
# Perfluoroalkyl sulfonamides (FASAs) in Untreated Well Water: April 2019

Private wells: black circles; Fountain: green triangles; Widefield: red squares; Security: blue diamonds

Generally, Private wells ~ Fountain < Widefield < Security

*\*All quantities are relative – no concentrations available*

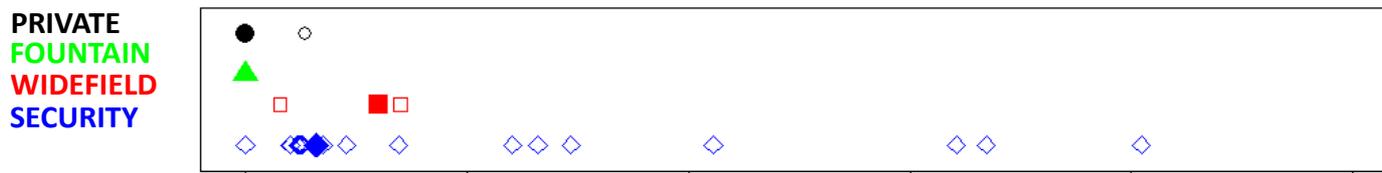
## FPrSA (C3)



## FBSA (C4)



## FPeSA (C5)



*Filled Shapes are Median: 50% of values are lower, 50% are greater, than this value*

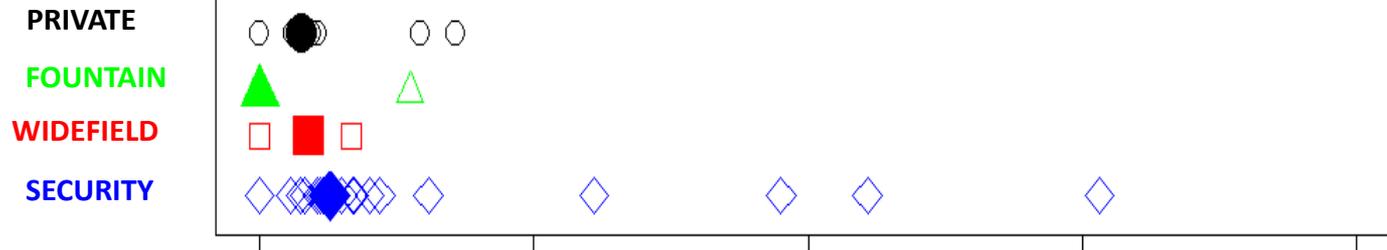
# Cyclic Sulfonate (PFEtCHxS) in Untreated Well Water: April 2019

**Private wells:** black circles; **Fountain:** green triangles; **Security:** blue diamonds; **Widefield:** red squares

Generally, **Private wells** ~ **Fountain** < **Widefield** < **Security**

*\*All quantities are relative – no concentrations available*

## PFEtCHxS



*Filled Shapes are **Median**: 50% of values are lower, 50% are greater, than this value*

## April 2019 Data Summary: PFASs in Untreated Well Water

**4 PFASs frequently detected (found in > 70% of samples) – shown in previous slides:**

- These PFASs are quite typical of AFFF-impacted groundwater
- C3-C5 perfluoroalkyl sulfonamides (FASAs) – FPrSA, FBSA, FPeSA
- One cyclic sulfonamide commonly detected – PFEtCHxS

**What was sporadically detected?**

Compounds	Percent Detection
<b>C6 FASA (FHxSA)</b>	32%
<b>C5, C6 Sulfinates (PFHxSi, PFPeSi)</b>	3%; 13%
<b>Keto-sulfonates (K-PFOS; K-PFHxS)</b>	8%; 3%
<b>Various substituted sulfonamides</b>	3-45%

## Next Analyses: Suspect Screening of Blood Samples

- **We have found additional PFASs in untreated drinking water beyond the regularly monitored compounds →**
  - **Are these compounds also in residents' blood samples?**
  - All blood sample data will also be screened for our list of ~1,400 AFFF-associated PFASs to see whether any additional compounds are present in blood
  - Like water data, results will not be quantitative, but will show:
    - **presence** of additional compounds if they are in the samples above detection limits
    - **relative abundance** compared to the other blood samples

# Future Directions

- We are currently scheduling for Year 2 blood sampling which will take place in May, 2019
- We will be doing detailed residential histories for as many participants as possible to help understand when the exposure may have started
- Currently doing data analysis and developing manuscripts for future presentations and publication in the scientific literature
- We are seeking funding for additional studies from federal sources

# PFAS UNITEDDD

## U.S. National Investigation of Transport and Exposure from Drinking Water and Diet

The U.S. Environmental Protection Agency's National Center for Environmental Research has granted \$1.9M of funding for research on the impact of PFAS to human health.



Investigators: **Christopher Higgins** (Colorado School of Mines); Tissa Illangasekare (Mines), Detlef Knappe (North Carolina State University); Jane Hoppin (NCSU); Heather Stapleton (Duke University); Courtney Carignan (Michigan State University); **John Adgate** (Colorado School of Public Health)



# Thank you for Coming!

If you are interested in getting updates related to this study, or learning about participation in future research, please enter your contact information on the sign-in sheet.

This work was funded by support from the National Institutes for Environmental Health Sciences R21-ES029394. Any opinions, findings conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of NIEHS.

For further questions:

**Email:** [PFAS-AWARE@UCDenver.edu](mailto:PFAS-AWARE@UCDenver.edu)

**Phone:** (719) 301-9733



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## Resources

See [www.PFAS-AWARE.org](http://www.PFAS-AWARE.org) for links

- [https://www.atsdr.cdc.gov/pfc/docs/pfas\\_clinician\\_fact\\_sheet\\_508.pdf](https://www.atsdr.cdc.gov/pfc/docs/pfas_clinician_fact_sheet_508.pdf)
- <https://www.epa.gov/pfas>
- <https://www.colorado.gov/pacific/cdphe/pfcs>
- <https://www.pfas-aware.org/>

# Extra Slides

- Slides from December meeting if people have questions on that data

Preliminary Blood Sampling Results  
from 220 Blood Samples:  
Review from December 2018

## Preliminary Blood Sampling-PFAS Results (in ng/ml):

Current Acronym	This Study 50 <sup>th</sup> Percentile	U.S. 50 <sup>th</sup> Percentile	This Study 90 <sup>th</sup> Percentile	U.S. 90 <sup>th</sup> Percentile	Percent Measurable
PFHxS	14.8	1.2	49.7	3.4	100
Total PFOS	9.7	4.8	28.1	13.2	100
Total PFOA	3.0	1.6	7.4	3.4	100
PFNA	0.4	0.6	0.8	1.4	100
PFHpS	0.2	N/A	0.6	N/A	82
PFDA	0.1	0.10	0.3	0.4	45
Me-FOSAA	0.1	< LOD	0.4	0.4	35
PFHxA	< LOD	N/A	0.2	N/A	25
PFUndA	0.1	< LOD	0.1	0.2	17
PFHpA	< LOD	< LOD	0.1	0.1	9
PFDoDA	< LOD	< LOD	0.1	< LOD	2
Et-FOSAA	< LOD	< LOD	0.1	< LOD	2

**<LOD stands for below the limit of detection.** This means that the value was somewhere between 0 and 0.1 ng/ml. Below 0.1 ng/ml the instrument cannot give a confident answer for the actual value.

# Summary: PFOS, PFOA, PFHxS and PFNA Numbers in F-S-W vs. CDC Reference Values

- PFHxS:
  - Median/90<sup>th</sup> percentile levels in F-S-W are ~12 times as high as the U.S. population reference levels
- PFOS:
  - Median/90<sup>th</sup> percentile levels in F-S-W are ~2 times as high as the U.S. population reference levels
- PFOA:
  - Median/90<sup>th</sup> percentile levels in F-S-W are ~2 times as high than the U.S. population reference levels
- PFNA:
  - Median/90<sup>th</sup> percentile levels in F-S-W are ~30 to 40% lower than the U.S. population reference levels

# Blood Sampling-Cholesterol Results:

	Total Cholesterol (mg/dL)	LDL (mg/dL)	HDL (mg/dL)	Triglycerides (mg/dL)
Study 50 <sup>th</sup> Percentile	<b>178</b>	<b>103</b>	<b>44</b>	<b>133</b>
Study Range	Min: <b>99</b> Max: <b>302</b>	Min: <b>38</b> Max: <b>207</b>	Min: <b>0</b> Max: <b>129</b>	Min: <b>34</b> Max: <b>499</b>
Expected Range	<b>Healthy:</b> Below 200 <b>Borderline High:</b> 200-239 <b>High:</b> 240 and above	<b>Healthy:</b> Below 100 <b>Borderline High:</b> 100-159 <b>High:</b> 160-189 <b>Very High:</b> 190 and above	<b>Low:</b> Below 40 <b>Borderline Low:</b> 40-59 <b>Healthy:</b> 60 and above	<b>Healthy:</b> Below 150 <b>Borderline High:</b> 150-199 <b>High:</b> 200-499 <b>Very High:</b> 500 and above

**If you are concerned about your results you should consult your physician.**

**We are still working on the analysis of any potential relationships between PFAS exposure and Cholesterol**

# Blood Sampling-Liver Enzyme Results:

	ALT (Units/L):	AST (Units/L):	GGT (Units/L):
Study 50 <sup>th</sup> Percentile Liver Enzyme Levels	Men: 16 Women: 12	Men and Women: 20	Men: 24 Women: 15
Study Range Liver Enzyme Levels	Men: 3 to 62 Women: 3 to 64	Men and Women: 10 to 60	Men: 6 to 151 Women: 6 to 79
Laboratory Reference Values for Liver Enzymes	Men: 0 to 44 Women: 0 to 32	Men and Women: 0 to 40	Men: 0 to 65 Women: 0 to 60

**If you are concerned about your results you should consult your physician.**

**We are still working on the analysis of any potential relationships between PFAS exposure and Liver Enzymes**